# METHOD OF IMPROVING THE BREAKDOWN VOLTAGE OF A DIFFUSED SEMICONDUCTOR JUNCTION

Inventors: Andrew Strachan and Vladislav Vashchenko

## TECHNICAL FIELD

The present invention utilizes the small volume implant effect to grade the doping profile and improve breakdown voltage of junctions formed in semiconductor integrated circuit structures.

## BACKGROUND OF THE INVENTION

Increasing the breakdown voltage of semiconductor junctions without reducing the doping levels is a common problem for new integrated circuit development.

Semiconductor junction breakdown is caused by the high electric field located at the junction. Various methods have been proposed to improve the breakdown for a given set of doping levels. These include grading the junction using multiple masks and/or multiple implants and using floating guard rings.

On heavily diffused junctions, multiple implants can cause problems due to unwanted vertical diffusion. To function properly, floating guard rings must be electrically isolated from the main junction; this is not possible with certain types of implants, such as n+ buried layers with overlying n-type epitaxial layer.

## DESCRIPTION OF THE DRAWINGS

Fig. 1 illustrates a conventional layout of a simple junction.

Fig. 2 illustrates a layout of a junction with a guard ring in accordance with the concepts of the present invention.

Fig. 3 illustrates a layout of a junction with grading islands in accordance with the concepts of the present invention.

Fig. 4 illustrates a layout of a junction with grading fingers in accordance with the concepts of the present invention.

Fig. 5 illustrates a doping profile of a semiconductor junction formed in accordance with the concepts of the present invention.

DESCRIPTION OF THE INVENTION

The present invention uses a single mask and a single implant to improve the breakdown voltage of a semiconductor junction over a conventional structure. The technique utilizes the "volume effect" of small implant windows to grade the doping of a single implant. The volume effect occurs when an implant is made through a small mask opening and the subsequent diffusion of the implant is large enough to drive dopant a distance greater than the size of the opening. Under these conditions, the doping at the center of the small mask opening will be lower than at the center of a larger mask opening. The technique works best with heavily diffused implants such as n+ buried layers.

Fig. 1 shows a conventional pn junction 100 formed at the interface between a semiconductor substrate 102 having a first conductivity type (e.g., P-type) and a dopant region 104 having a second conductivity type (e.g., N-type) opposite the first conductivity type formed in the semiconductor substrate 102. The shape of the region is unimportant, being illustrated as square in Fig. 1.

Fig. 2 shows a modified version of the Fig. 1 junction layout with a guard ring 106. The guard ring 106 is formed with the minimum possible masking dimension. That is, the mask opening utilized to introduce dopant atoms into the semiconductor substrate 102 to form the guard ring 106 is the minimum width that can be achieved with the particular integrated circuit fabrication process in use. The separation between the guard ring 106 and the primary junction 100 is selected to align with the lateral diffusion of the junction. This technique requires that the junction from the guard ring overlap (i.e. be contiguous with) the primary junction 100 after a subsequent thermal diffusion step. A conventional floating guard ring structure would require that the dopant ring to be placed further away so as to isolate the ring junction from the main junction after the diffusion step. This explains why the technique of the present invention can be used for n+ buried layer implants into a p-type substrate, which is then capped with n-type epitaxy. In this structure, no floating n-type layers are possible.

Fig. 3 shows an alternate embodiment of the present invention. In the Fig. 3 junction structure, minimum geometry dopant islands 108 are formed around the primary junction 100. Again, the distance from the dopant islands 108 to the primary junction 100 is chosen to align with the lateral diffusion of the junction.

Fig. 4 shows another alternate implementation of the invention using dopant fringes 110. In this case, dopant fringes 110 are formed along the edge of the primary junction 100 on all four sides of the dopant region 104. Again, the size and pitch of the fringes 110 are the minimum possible masking dimension. The length of the fringes 110 must be greater than the diffusion of the implant. The fringe length in the Fig. 4 embodiment roughly corresponds to the extent of the islands 108 in the Fig. 3 embodiment.

The junction structures resulting from the Fig. 2, 3 and 4 embodiments of the invention increase breakdown voltage by grading the doping profile of the junction even though only a single implant is used. To work, the minimum geometry of the ring 106 in the Fig. 2 embodiment, or the islands 108 in the Fig. 3, or the fringes in the Fig. 4 embodiment must be less than two times (2x) the lateral diffusion length of the junction during the thermal diffusion step. As is well known, the minimum geometry mask openings will restrict the amount of dopant that can be placed in the ring 106, the islands 108, or the fringes 110, relative to the amount of dopant that is placed in the primary dopant region 104. If the above restriction on minimum opening versus diffusion length is met, then the doping under the center of the mask opening will be reduced with respect to the doping under the center of the primary junction. That is, for example, the doping at location X in the Fig. 3 embodiment is less than doping at location Y. This grading of the junction improves the breakdown voltage of the junction.

Fig. 5 shows the representation of a doping profile of a semiconductor junction formed in accordance with the Figs. 2, 3 or 4 embodiments of the invention. This cross section corresponds to a section from point Y through point X in Fig. 3. A single n+ implant is made through the mask as drawn and there is a subsequent diffusion. The resulting doping profile shows a primary doping profile from the large mask opening to the left. The small

mask opening generates a lower peak doping level that is diffused to join the primary doping profile. The lower doped region acts as an extension to the primary junction and grades the doping of the n+ implant. The particular structure shown in the Fig. 5 representation is an n+ buried layer on a p-substrate with an overlying n-type epitaxial layer, which is a typical application for the present invention.

Although only specific embodiments of the present invention are shown and described herein, the invention is not to be limited by these embodiments. Rather, the scope of the invention is to be defined by these descriptions taken together with the attached claims and their equivalents.